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RESEARCH AT THE BIDSTON BRANCH OF THE UK INSTITUTE OF OCEANOGRAPHIC SCIENCES

WAYNE V. BURT

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The background of IOS Bidston is presented along with a short history of its predecessors, the Liverpool Observatory, the Liverpool Tidal Institute, and the Institute of Coastal Oceanography and Tides. Ongoing research programs at IOS Bidston are described.


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# RESEARCH AT THE BIDSTON BRANCH OF THE UK INSTITUTE OF OCEANOGRAPHIC SCIENCES

The UK Institute of Oceanographic Sciences (IOS), financed by the Natural Environment Research Council (NERC), was established in 1973 by combining the National Institute of Oceanography, the Institute of Coastal Oceanography and Tides, and the Unit of Coastal Sedimentation. The work of the Institute is divided among three laboratories located at Wormley, Taunton, and Bidston. A brief history of the Bidston Branch with some of its research programs and service functions are given here (see also ONRL Technical Reports 33-58 and 14-62).

Prior to 1945, the Bidston Branch was called the Liverpool Tidal Institute and was housed in the former Liverpool Observatory on Bidston Hill, a prominent landmark on the seaward end of the range of hills in the center of the peninsula separating the Mersey and Dee River estuaries. The observatory sits within a stone-walled square in the center of a 70-acre public park that has been left in its natural wild state. The site has a centuries-old connection with the sea. Foot square holes are lined along the bare stone top of the ridge. Starting in the 17th century, lookouts with telescopes were stationed here to locate and identify ships headed for Liverpool Harbor. As soon as a ship was spotted, a flag identifying it was run up one of the signal masts that was seated in one of the square holes in the rock. In this way the ship's arrival was relayed to watchers in Liverpool several hours before it arrived.

The Observatory was established in Liverpool in 1845 and moved to the Bidston Hill site in 1864. Its primary purpose was to determime time accurately from astronomical observations and then relay the correct time to ships within the harbor at Liverpool. A lighthouse was added to the observatory grounds in 1873. The Observatory became obsolete with the advent of radio and in broadcasting the correct time from the Royal Observatory at Greenwich. The Observatory is also one of the oldest weather stations in Europe, having been in continuous operation for 112 years.

Joseph Proudman (1888-1975) created the "Liverpool Tidal Institute" in March 1919, on being appointed Professor of Applied Mathematics of Liverpool University, at the age of 30. His interest in tidal theory was first stimulated by Professor Horace Lamb of Manchester and resulted in a long series of research papers on tides and other oceangraphic topics spanning an active career of about 48 years. The Tidal Institute was founded by the University with the encouragement of Lamb and the financial backing of Cunard and Booth Shipping Companies, with Proudman as Director and his former student Arthur Doodson as Secretary. Its objectives in brief, were to carry out research into all aspects of tides and similar motions of the sea, and to set up a national center for organized tidal information including predictions. Proudman and Doodson were its most famous and productive workers, but distinguished work was also done in its later years

by S.F. Grace, R.H. Corkan, and J.R. Rossiter.

In 1933 Proudman transferred to the University's Chair of Oceanography, and in 1945 he resigned his directorship of the Tidal Institute in favor of Doodson. However, he continued to serve on its governing council and was very active in national and international oceanographic affairs, particularly in the formation in 1950 of the "National Institute of Oceanography" (now IOS) at Wormley, Surrey under the directorship of Dr. (later Sir) George Deacon.

The Tidal Institute was given a room at the Observatory in 1924 and was granted complete occupation in 1929 when the last Observatory director died and it ceased to function as an astronomical observatory. During its first half century the Tidal Institute became one of the world's leading centers for tidal research and especially tidal prediction. Originally set up to predict tides for UK ports (85 in all), the Institute branched out and made tidal predictions for harbors all over the world. Predictions were made through contracts with the ports concerned, thus making the Institute self-supporting.

The Tidal Institute was housed in the old sandstone building of the observatory, dating from the 1870's. The cavernous two-story basement below the building was the quarry for the rock used in the building's construction. The basement was used for geophysical observations of tidal variations in gravity and earth tilt.

During its 50th anniversary year (1969) the financing of the Tidal Institute was taken over by NERC and renamed the Institute of Coastal Oceanography and Tides (ICOT). A big expansion began and sea-going research projects—wave research, coastal oceanography, and shelf and deep sea tidal research—were added to ongoing programs. As previously mentioned, in 1973 the NERC formed the Institute of Oceanographic Sciences, and the ICOT became the IOS Bidston. Its programs and financing are closely linked with the principal IOS at Wormley near London and the IOS Taunton. The combining of these laboratories was accompanied by a major shuffle of programs among them. Coastal research was moved from Bidston to Taunton. Wave research at all three laboratories was split into two sections, the theoretical studies of ocean waves staying at Wormley and the observational and engineering wave studies moving to Taunton. The group working on ocean tides at Wormley was moved to Bidston. The head of the group, Dr. David Cartwright, became head of IOS Bidston.

A lovely new white building was completed in 1975 and named after Joseph Proudman in 1979. It has spacious, unusually neat high ceiling shops, storage, and staging areas in the ground floor—half basement. The other two floors have many windows brightening up the interior and offering beautiful views in all directions from the hill-top site.

The Institute still has close ties with the Departments of Mathematics and Oceanography at the Univ. of Liverpool. The IOS senior staff are fellows

at the University, and several lecture regularly in the Departments mentioned above. The Institute usually has a few of the University's graduate students doing research on their PhD degrees.

From time to time individuals from developing countries visit IOS Bidston to learn tide prediction techniques.

Bidston serves one very important function for all three IOS laboratories; it houses their computer center. Rented lines are used to connect terminals at Wormley and Taunton with the medium-sized Honeywell 66/20 at Bidston. The computing center Bidston is also interlinked with several other larger computer centers in the UK, including the Rutherford Laboratory at Harwell and the Science Research Council Computer center in Daresbury. It has built up a very effective computing team.

At the present time IOS Bidston has a total complement of about 90 persons.

Cartwright has been working on tidal theory and carrying out observational studies on tides and other long waves in the sea for many years. In 1969 his team at Wormley was successful in developing a sea-floor tide gauge and began studies on the continental shelf around Great Britain. With 16 shelf stations recording pressure and currents, he was able to do a tidal budget of energy coming into the North Sea and to compute the dissipation of tidal energy over the continental shelf caused by tidal friction on the bottom.

IOS Bidston now builds its own shelf and open ocean tide gauges using some components from Aanderaa in Norway and Canada. The data from quartz crystal sensors is recorded on magnetic tape casettes. Two gauges are deployed on each mooring for redunduncy in case one or the other guage doesn't work properly. The continental shelf models either drop their weights and pop up to the surface when an acoustic release is triggered or they are fastened to a surface float or buoy with a recovery line. A third system used in shallow water is to fasten a ground line to the gauges. Recovery is accomplished by dragging for the attached line. Deep sea gauges can be placed on the bottom and will pop up to the surface after the anchor weights have been released acoustically.

Theoretically, deep sea tide gauges can be left out for six months, and they could stay down for a year with increased cassette and power capacity. However, in practice, they are usually operated for about a month at a time.

Cartwright now has about 50 good deep sea tidal records. He is running a latitudinal line of tide stations across the North Atlantic at 53 1/2° N and is boxing off the North Atlantic in big 20° squares to study the deep ocean tides. His latest measurements came from seven gauges that were placed on the form bottom along a line from Sierra Leone, Africa through St. Paul's rocks near the Equator to stations off the coast of Brazil.

Dr. David Pugh is studying tides and sea level changes in the Indian Ocean. This includes a study of anomalous tidal features off the Somali Coast. He has also measured the tides near amphidromic points. Next year he plans to study the tides with a number of gauges around a 1,000 km triangle south of the Chagos Islands. He has also placed a tide gauge in the Chagos Islands to study a persistent 45 min. seiche with a height between 10 and 100 cm. This same feature is also found in the Seychelles.

The dynamic modeling group is headed by Dr. N.S. Heaps. It is concerned with developing numerical and mathematical models of the British continental shelf seas, the North Sea, and the adjacent oceans. Heaps and his assistant, Mr. J.E. Jones, are presently working on a 3D model of the currents in the Irish Sea. Heaps also supervises two PhD candidates who are at Bidston on NERC fellowships. Mr. A. Owens is working on tide and surge modeling in the British Channel and the Celtic Sea to the west of Cornwall with applications to possible tidal power schemes. The very high tides in the study area make it an attractive place for erecting barriers for the purpose of generating electricity from tidal flow. The 64 dollar question is, what effects will barriers have on the tides themselves. For example, the several models that have been generated for the Severn River estuary are not in agreement as to whether a barrier would increase or decrease the vertical range of the tides.

Heaps' second student, Mr. R. Proctor, is making a current circulation study of the Northern Irish Sea.

There has been a long-time (15 years) continuing concentration on storm surge forecasting as well as a study of the statistical probability of storm surges exceeding certain critical evaluations in various locations around the British Isles. Potential damage from storm surges is a multimillion dollar hazard in some locations. For example, in London, maps are posted in subway stations and other prominent places showing the areas of the city that could be flooded by disastrous storm surges in the Thames, along with instructions for evacuation in the event that such surges are forecast. Sea level is slowly rising in the Thames River estuary area, increasing the possibility of flooding. The problem has become so acute that a storm surge barrier is being constructed across the Thames River at Woolwich, 17 km below the Tower Bridge. The barrier will consist of large gates which are designed to remain open most of the time to allow free passage of ships and the astronomical tides.

Most of the large storm surges that affect the Thames River estuary are external to the North Sea. They are set up by slowly moving or nearly stationary storms over the shallow continental shelf west of Scotland. They then move as progressive shallow water waves around the northern tip of Scotland and down the east coast of England. Their southward passage is monitored by six tide gauges located between the north tip of Scotland (Wick) and the mouth of the Thames. Accurate methods have been developed to forecast these surges from prognostic air pressure charts of the generating area from which the surface wind field is derived. The accuracy of

these forecasts is currently limited by the accuracy of the prognostic charts.

Fortunately the external surges that affect the Thames area appear to undergo nonlinear interactions with the dominant $M_2$ semi-diurnal lunar tidal component in such a way that the two waves are usually out of phase when they move up the Thames River estuary. Thus, only a few times a year will the external surges be large enough in themselves to require the closing of the Woolwich barrier after it has been completed. Ample time (ten hours) will be available to close the barrier (which requires about six hours) after the surge has been forecast and its passage at the Wick tidal station is noted.

The most vexing problems to IOS Bidston are internal surge components that are generated by the winds over the North Sea. These either may be a simple set-up caused by strong persistent winds from northerly directions, or occur when the wind dies down and changes direction. Under these conditions standing waves may slop back and forth in the North Sea. Forecasting storm surge components internal to the North Sea is more difficult than forecasting external surges. Usually the warning time is relatively short compared to that required to close the Thames' barrier. The internal surge components appear to be uncoupled from both the external surges and the astronomical tides. Thus, although the internal surges may have relatively small amplitudes compared to external surges and astronomical tides, if the internal surges are in phase with either the external surges or $M_2$ tides, they may raise the water level in the Thames at London to dangerous flooding levels. The key to the successful use of the Thames barrier will lie in learning to forecast internal surges far enough in advance of their arrival at Woolwich to allow the barrier gates to be closed. Thus, IOS Bidston is putting a lot of effort into improving internal surge models.

Dr. R.A. Flather and Dr. A. Davies collaborate on the 2D nonlinear shelf-sea model which is directly geared to the UK Meteorological Office numerical forecasts for surface, atmospheric pressure, and surface wind. The model, developed as a tool for forecasting storm surges, was used operationally by the Met. Office for the first time during the 1978/79 winter. Flather is also developing a tidal model covering the shelf around the UK and Ireland and part of the Atlantic Ocean. Davies is investigating a 3D model for currents and a fine mesh 2D model of the North Sea.

Dr. D. Prandle has been working on the use of a nonlinear model of the southern North Sea/Dover Strait area to investigate surge tide interaction, residual flows, and coastal mean sea level. Mrs. J. Wolf is combining Prandle's model with one of the Thames estuary for forecasting surge heights in the vicinity of the Woolwich barrier.

The instrument section under Mr. Joseph Rae is unique in that the same teams of technicians not only design and construct most of the equipment but also get the equipment ready to go to sea, organize the cruise, deploy the equipment at sea, recover it and make it ready for the next

cruise. Finally, they translate the magnetic data tapes into computer compatible form and check the actual data to see if it is good. They have found that this system works very well and no one can pass the buck onto someone else in case of errors. In some cases they use Aanderaa current meters and tide gauges, but they often use just the Aanderaa data loggers with their own sensors. They have a field station at Holyhead, Wales for checking coastal equipment under field conditions.

The geophysics group under Dr. T.F. Baker have two Lacoste-Romberg instruments to measure earth tides. These are tested in the virgin rock basement of the old observatory building. Because of their location between the Mersey and Dee estuaries, the tide loading caused by changing depths of water over the bottom is comparatively large, about 20% of the signal.

Baker's group has recently begun a program of measuring the earth's tidal tilt at a site in Cumbria with Askania bore hole pendulums. The resulting signals showed excursions of over 100 m/sec that were correlated with atmospheric pressure, temperature, and rainfall. However, the strongest correlations were with ground water level through some undefined complex interaction process. Baker feels that he has a long way to go in his research before he can confidently use tilt as a geophysical tool to study crystal structures. One of his goals is to use the bore hole pendulum in an inverse process to determine oceanic tides.

Dr. John Huthnance is continuing his research on coastal trapped waves in a stratified ocean. This is a continuation of his research on waves trapped over Rockall Plateau, a submerged sub-continental land mass west of Scotland. These waves have periods up to several days and show up as surface elevation changes in tidal records as well as in shelf current meter data.

Huthnance is also carrying out a long-term theoretical study that was started from the fact that the diurnal tidal components in the Atlantic Ocean have some very odd characteristics. One would expect that the phase angles of $O_1$ and $K_1$ would be about the same. This is true on the east coast of the US where the difference in phase angles varies from 30° down to 0°. Around the UK the phase angles vary greatly and may be as great as 120°. This is not a local effect but prevails along the eastern North Atlantic Ocean with phase angle differences of 100° off Northwest Africa, growing to 130° to 140° off Norway.

Huthnance describes his model as "rather tortuous." However, he does have it in the computer and working, and a paper on the subject is in draft form. His basic conclusion is that tidal energy flows northward from the South Atlantic Ocean into the North Atlantic where the two oceans join. This effect goes all the way to Norway and the Arctic Ocean. His reasoning is based on the fact that the nature of the co-tidal lines in the two oceans is quite different, causing various interactions where the two oceans join.

Dr. I.D. James has been concerned mainly with frontal systems, the near-surface thermal structure, heat budgets, and mixing in shallow seas. This summer he plans to take part in the Marine Remote Sensing exercise (MARSEN) in the German Bight. He will use the research vessel *JOHN MURRAY* for two weeks to obtain ground truth from moored current meters and bottom mounted tide gauges. He will also do a temperature and salinity survey of the area.

Mr. G.A. Alcock has spent a great deal of time analyzing records of electrical potential and current in telephone cables across the English channel to determine residual currents for modeling flow in and out of the North Sea. More recently he has been collaborating with Cartwright on a study of Groves and Reynolds concept of (orthotides) tidal analysis on two series of tidal records (*Journal of Geophysics Research* 80, 4131-4138).

At the present time Alcock is working with Cartwright on "SeaSat" altimetry. He is calculating the deformation of local sea areas caused by tides and weather, for all relevant "SeaSat" passes. When this has been done, they plan to confer with geodesists for an exchange of oceanographic, geodetic, orbital, and altimetric data in order to determine whether they can make a significant reduction of residual variance when oceanographic data is added to the altimetric equation. The problem is a very complicated one and includes considering storm surges from their latest models, earth tides, marine tides (bascially $M_2$ and its higher harmonics), long period tidal effects, and low-frequency effects owing to large scale weather forcing. If the above proves to be successful, they plan to use "SeaSat" data in other areas for the determination of tides where little is known about them. The service functions of IOS Bidston will be described in a future issue of *ESN*.